Statistical Significance and Univariate and Bivariate Tests

BUS 735: Business Decision Making and Research

Goals

- Specific goals:
  - Re-familiarize ourselves with basic statistics ideas: sampling distributions, hypothesis tests, p-values.
  - Be able to distinguish different types of data and prescribe appropriate statistical methods.
  - Conduct a number of hypothesis tests using methods appropriate for questions involving only one or two variables.
- Learning objectives:
  - LO1: Be able to construct and test hypotheses using a variety of bivariate statistical methods to compare characteristics between two populations.
  - LO6: Be able to use standard computer packages such as SPSS and Excel to conduct the quantitative analyses described in the learning objectives above.

Goals

- Specific goals:
    - Re-familiarize ourselves with basic statistics ideas: sampling distributions, hypothesis tests, p-values.
    - Be able to distinguish different types of data and prescribe appropriate statistical methods.
    - Conduct a number of hypothesis tests using methods appropriate for questions involving only one or two variables.
- Learning objectives:
    - LO1: Be able to construct and test hypotheses using a variety of bivariate statistical methods to compare characteristics between two populations.
    - LO6: Be able to use standard computer packages such as SPSS and Excel to conduct the quantitative analyses described in the learning objectives above.

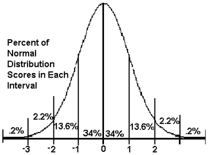
Agenda

Learning Objective	Active Learning Activity
Re-familiarize ourselves with basic statistics ideas: sampling distributions, hypothesis tests, p-values.	Lecture / Discussion
Be able to distinguish different types of data.	Lecture / Discussion
Learn and conduct hypothesis tests on single variables.	Learn by doing: work together on examples using SPSS.
Learn and conduct hypothesis tests for differences between two variables.	Learn by doing: work together on examples using SPSS.
Practice makes perfect!	Worksheet, work with your neighbor.
More practice!	Homework assignment, due Tuesday, Sept 10 (if we get far enough)

Probability Distribution

- **Probability distribution:** summary of all possible values a variable can take along with the probabilities in which they occur.
- Usually displayed as:

Picture



Table

z	0.00	0.01	0.02	0.03	0.04	0.05
0.0	0.5000	0.5040	0.5080	0.5120	0.5159	0.5199
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749

Formula

$$f(x|\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\left(\frac{(x-\mu)^2}{2\sigma^2}\right)}$$

- **Normal distribution:** often used "bell shaped curve", reveals probabilities based on how many standard deviations away an event is from the mean.

Sampling distribution

- Imagine taking a sample of size 100 from a population and computing some kind of statistic.
- The statistic you compute can be anything, such as: mean, median, proportion, difference between two sample means, standard deviation, variance, or anything else you might imagine.
- Suppose you repeated this experiment over and over: take a sample of 100 and compute and record the statistic.
- A **sampling distribution** is the probability distribution *of the statistic*
- Is this the same thing as the probability distribution of the population?

Sampling distribution

- Imagine taking a sample of size 100 from a population and computing some kind of statistic.
- The statistic you compute can be anything, such as: mean, median, proportion, difference between two sample means, standard deviation, variance, or anything else you might imagine.
- Suppose you repeated this experiment over and over: take a sample of 100 and compute and record the statistic.
- A **sampling distribution** is the probability distribution *of the statistic*
- Is this the same thing as the probability distribution of the population?

Sampling distribution

- Imagine taking a sample of size 100 from a population and computing some kind of statistic.
- The statistic you compute can be anything, such as: mean, median, proportion, difference between two sample means, standard deviation, variance, or anything else you might imagine.
- Suppose you repeated this experiment over and over: take a sample of 100 and compute and record the statistic.
- A **sampling distribution** is the probability distribution *of the statistic*
- Is this the same thing as the probability distribution of the population?

Sampling distribution

- Imagine taking a sample of size 100 from a population and computing some kind of statistic.
- The statistic you compute can be anything, such as: mean, median, proportion, difference between two sample means, standard deviation, variance, or anything else you might imagine.
- Suppose you repeated this experiment over and over: take a sample of 100 and compute and record the statistic.
- A **sampling distribution** is the probability distribution *of the statistic*
- Is this the same thing as the probability distribution of the population?

Sampling distribution

- Imagine taking a sample of size 100 from a population and computing some kind of statistic.
- The statistic you compute can be anything, such as: mean, median, proportion, difference between two sample means, standard deviation, variance, or anything else you might imagine.
- Suppose you repeated this experiment over and over: take a sample of 100 and compute and record the statistic.
- A **sampling distribution** is the probability distribution *of the statistic*
- Is this the same thing as the probability distribution of the population?

Sampling distribution

- Imagine taking a sample of size 100 from a population and computing some kind of statistic.
- The statistic you compute can be anything, such as: mean, median, proportion, difference between two sample means, standard deviation, variance, or anything else you might imagine.
- Suppose you repeated this experiment over and over: take a sample of 100 and compute and record the statistic.
- A **sampling distribution** is the probability distribution *of the statistic*
- Is this the same thing as the probability distribution of the population?
  NO! They may coincidentally have the same shape though.

Example

- Sampling Distribution Simulator
- In reality, you only do an experiment once, so the sampling distribution is a hypothetical distribution.
- Why are we interested in this?

Example

- Sampling Distribution Simulator
- In reality, you only do an experiment once, so the sampling distribution is a hypothetical distribution.
- Why are we interested in this?

Example

- Sampling Distribution Simulator
- In reality, you only do an experiment once, so the sampling distribution is a hypothetical distribution.
- Why are we interested in this?

Desirable qualities

What are some qualities you would like to see in a sampling distribution?

Desirable qualities

What are some qualities you would like to see in a sampling distribution?

- The average of the sample statistics is equal to the true population parameter.

Desirable qualities

What are some qualities you would like to see in a sampling distribution?

- The average of the sample statistics is equal to the true population parameter.
- Want the variance *of the sampling distribution* to be as small as possible. Why?

Desirable qualities

What are some qualities you would like to see in a sampling distribution?

- The average of the sample statistics is equal to the true population parameter.
- Want the variance *of the sampling distribution* to be as small as possible. Why?
- Want the *sampling distribution* to be normal, regardless of the distribution of the population.

Central Limit Theorem

- Given:
  - Suppose a RV x has a distribution (it need not be normal) with mean μ and standard deviation σ.
  - Suppose a *sample mean* ($\bar{x}$) is computed from a sample of size n.
- Then, if n is sufficiently large, the sampling distribution of $\bar{x}$ will have the following properties:
  - The sampling distribution of $\bar{x}$ will be normal.
  - The mean of the sampling distribution will equal the mean of the population (consistent):

$$\mu_{\bar{x}} = \mu$$

  - The standard deviation of the sampling distribution will decrease with larger sample sizes, and is given by:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Central Limit Theorem

- Given:
  - Suppose a RV x has a distribution (it need not be normal) with mean μ and standard deviation σ.
  - Suppose a *sample mean* ($\bar{x}$) is computed from a sample of size n.
- Then, if n is sufficiently large, the sampling distribution of $\bar{x}$ will have the following properties:
  - The sampling distribution of $\bar{x}$ will be normal.
  - The mean of the sampling distribution will equal the mean of the population (consistent):

$$\mu_{\bar{x}} = \mu$$

  - The standard deviation of the sampling distribution will decrease with larger sample sizes, and is given by:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Central Limit Theorem

- Given:
  - Suppose a RV x has a distribution (it need not be normal) with mean μ and standard deviation σ.
  - Suppose a *sample mean* ($\bar{x}$) is computed from a sample of size n.
- Then, if n is sufficiently large, the sampling distribution of $\bar{x}$ will have the following properties:
  - The sampling distribution of $\bar{x}$ will be normal.
  - The mean of the sampling distribution will equal the mean of the population (consistent):

$$\mu_{\bar{x}} = \mu$$

  - The standard deviation of the sampling distribution will decrease with larger sample sizes, and is given by:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Central Limit Theorem

- Given:
  - Suppose a RV x has a distribution (it need not be normal) with mean μ and standard deviation σ.
  - Suppose a *sample mean* ($\bar{x}$) is computed from a sample of size n.
- Then, if n is sufficiently large, the sampling distribution of $\bar{x}$ will have the following properties:
  - The sampling distribution of $\bar{x}$ will be normal.
  - The mean of the sampling distribution will equal the mean of the population (consistent):

$$\mu_{\bar{x}} = \mu$$

  - The standard deviation of the sampling distribution will decrease with larger sample sizes, and is given by:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Central Limit Theorem

- Given:
  - Suppose a RV x has a distribution (it need not be normal) with mean μ and standard deviation σ.
  - Suppose a *sample mean* ($\bar{x}$) is computed from a sample of size n.
- Then, if n is sufficiently large, the sampling distribution of $\bar{x}$ will have the following properties:
  - The sampling distribution of $\bar{x}$ will be normal.
  - The mean of the sampling distribution will equal the mean of the population (consistent):

$$\mu_{\bar{x}} = \mu$$

  - The standard deviation of the sampling distribution will decrease with larger sample sizes, and is given by:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Central Limit Theorem

- Given:
  - Suppose a RV x has a distribution (it need not be normal) with mean μ and standard deviation σ.
  - Suppose a *sample mean* ($\bar{x}$) is computed from a sample of size n.
- Then, if n is sufficiently large, the sampling distribution of $\bar{x}$ will have the following properties:
  - The sampling distribution of $\bar{x}$ will be normal.
  - The mean of the sampling distribution will equal the mean of the population (consistent):

$$\mu_{\bar{x}} = \mu$$

  - The standard deviation of the sampling distribution will decrease with larger sample sizes, and is given by:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Central Limit Theorem

- Given:
  - Suppose a RV x has a distribution (it need not be normal) with mean μ and standard deviation σ.
  - Suppose a *sample mean* ($\bar{x}$) is computed from a sample of size n.
- Then, if n is sufficiently large, the sampling distribution of $\bar{x}$ will have the following properties:
  - The sampling distribution of $\bar{x}$ will be normal.
  - The mean of the sampling distribution will equal the mean of the population (consistent):

$$\mu_{\bar{x}} = \mu$$

  - The standard deviation of the sampling distribution will decrease with larger sample sizes, and is given by:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Central Limit Theorem: Small samples

If n is small (rule of thumb for a single variable: $n < 30$)

- The sample mean is still consistent.
- Sampling distribution will be normal if the distribution of the population is normal.

Central Limit Theorem: Small samples

If n is small (rule of thumb for a single variable: $n < 30$)

- The sample mean is still consistent.
- Sampling distribution will be normal if the distribution of the population is normal.

Example 1

Suppose average birth weight is $\mu = 7lbs$, and the standard deviation is $\sigma = 1.5lbs$.

What is the probability that a sample of size $n = 30$ will have a mean of $7.5lbs$ or greater?

Example 1

Suppose average birth weight is $\mu = 7lbs$, and the standard deviation is $\sigma = 1.5lbs$.

What is the probability that a sample of size $n = 30$ will have a mean of $7.5lbs$ or greater?

Example 1

Suppose average birth weight is $\mu = 7lbs$, and the standard deviation is $\sigma = 1.5lbs$.

What is the probability that a sample of size $n = 30$ will have a mean of $7.5lbs$ or greater?

$$z = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}} = \frac{\bar{x} - \mu}{\sigma / \sqrt{n}}$$

Example 1

Suppose average birth weight is $\mu = 7 lbs$, and the standard deviation is $\sigma = 1.5 lbs$.

What is the probability that a sample of size $n = 30$ will have a mean of $7.5 lbs$ or greater?

$$z = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}} = \frac{\bar{x} - \mu}{\sigma / \sqrt{n}}$$

$$z = \frac{7.5 - 7}{1.5 / \sqrt{30}} = 1.826$$

Example 1

Suppose average birth weight is $\mu = 7 lbs$, and the standard deviation is $\sigma = 1.5 lbs$.

What is the probability that a sample of size $n = 30$ will have a mean of $7.5 lbs$ or greater?

$$z = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}} = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}}$$

$$z = \frac{7.5 - 7}{1.5/\sqrt{30}} = 1.826$$

The probability the sample mean is greater than $7.5 lbs$ is:

Example 1

Suppose average birth weight is $\mu = 7lbs$, and the standard deviation is $\sigma = 1.5lbs$.

What is the probability that a sample of size $n = 30$ will have a mean of $7.5lbs$ or greater?

$$z = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}} = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}}$$

$$z = \frac{7.5 - 7}{1.5/\sqrt{30}} = 1.826$$

The probability the sample mean is greater than $7.5lbs$ is:

$$P(\bar{x} > 7.5) = P(z > 1.826) = 0.0339$$

Example 2

Suppose average birth weight is $\mu = 7lbs$, and the standard deviation is $\sigma = 1.5lbs$.

What is the probability that a randomly selected baby will have a weight of 7.5lbs or more? What do you need to assume to answer this question?

Example 2

Suppose average birth weight is $\mu = 7 lbs$, and the standard deviation is $\sigma = 1.5 lbs$.

What is the probability that a randomly selected baby will have a weight of 7.5lbs or more? What do you need to assume to answer this question?

Example 2

Suppose average birth weight is $\mu = 7lbs$, and the standard deviation is $\sigma = 1.5lbs$.

What is the probability that a randomly selected baby will have a weight of 7.5lbs or more? What do you need to assume to answer this question?

Must assume the population is normally distributed. Why?

Example 2

Suppose average birth weight is $\mu = 7 lbs$, and the standard deviation is $\sigma = 1.5 lbs$.

What is the probability that a randomly selected baby will have a weight of 7.5lbs or more? What do you need to assume to answer this question?

Must assume the population is normally distributed. Why?

$$z = \frac{x - \mu}{\sigma} = \frac{7.5 - 7}{1.5} = 0.33$$

Example 2

Suppose average birth weight is $\mu = 7 lbs$, and the standard deviation is $\sigma = 1.5 lbs$.

What is the probability that a randomly selected baby will have a weight of 7.5lbs or more? What do you need to assume to answer this question?

Must assume the population is normally distributed. Why?

$$z = \frac{x - \mu}{\sigma} = \frac{7.5 - 7}{1.5} = 0.33$$

The probability that a baby is greater than 7.5lbs is:

Example 2

Suppose average birth weight is $\mu = 7lbs$, and the standard deviation is $\sigma = 1.5lbs$.

What is the probability that a randomly selected baby will have a weight of 7.5lbs or more? What do you need to assume to answer this question?

Must assume the population is normally distributed. Why?

$$z = \frac{x - \mu}{\sigma} = \frac{7.5 - 7}{1.5} = 0.33$$

The probability that a baby is greater than 7.5lbs is:

$$P(x > 7.5) = P(z > 0.33) = 0.3707$$

Example 3

- Suppose average birth weight of all babies is $\mu = 7 lbs$, and the standard deviation is $\sigma = 1.5 lbs$.
- Suppose you collect a sample of 30 newborn babies whose mothers smoked during pregnancy.
- Suppose you obtained a sample mean $\bar{x} = 6 lbs$. If you assume the mean birth weight of babies whose mothers smoked during pregnancy has the same sampling distribution as the rest of the population, what is the probability of getting a sample mean this low or lower?

Example 3

- Suppose average birth weight of all babies is $\mu = 7lbs$, and the standard deviation is $\sigma = 1.5lbs$.
- Suppose you collect a sample of 30 newborn babies whose mothers smoked during pregnancy.
- Suppose you obtained a sample mean $\bar{x} = 6lbs$. If you assume the mean birth weight of babies whose mothers smoked during pregnancy has the same sampling distribution as the rest of the population, what is the probability of getting a sample mean this low or lower?

Example 3

- Suppose average birth weight of all babies is $\mu = 7lbs$, and the standard deviation is $\sigma = 1.5lbs$.
- Suppose you collect a sample of 30 newborn babies whose mothers smoked during pregnancy.
- Suppose you obtained a sample mean $\bar{x} = 6lbs$. If you assume the mean birth weight of babies whose mothers smoked during pregnancy has the same sampling distribution as the rest of the population, what is the probability of getting a sample mean this low or lower?

Example 3 continued

$$z = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}} = \frac{\bar{x} - \mu}{\sigma / \sqrt{n}}$$

Example 3 continued

$$z = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}} = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}}$$

$$z = \frac{6 - 7}{1.5/\sqrt{30}} = -3.65$$

Example 3 continued

$$z = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}} = \frac{\bar{x} - \mu}{\sigma / \sqrt{n}}$$

$$z = \frac{6 - 7}{1.5 / \sqrt{30}} = -3.65$$

The probability the sample mean is less than or equal to 6*lbs* is:

Example 3 continued

$$z = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}} = \frac{\bar{x} - \mu}{\sigma / \sqrt{n}}$$

$$z = \frac{6 - 7}{1.5/\sqrt{30}} = -3.65$$

The probability the sample mean is less than or equal to 6*lbs* is:

$$P(\bar{x} < 6) = P(z < -3.65) = 0.000131$$

Example 3 continued

$$z = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}} = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}}$$

$$z = \frac{6 - 7}{1.5/\sqrt{30}} = -3.65$$

The probability the sample mean is less than or equal to 6*lbs* is:

$$P(\bar{x} < 6) = P(z < -3.65) = 0.000131$$

That is, if smoking during pregnancy actually does still lead to an average birth weight of 7 pounds, there was only a 0.000131 (or 0.0131%) chance of getting a sample mean as low as six or lower.

Example 3 continued

$$z = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}} = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}}$$

$$z = \frac{6 - 7}{1.5/\sqrt{30}} = -3.65$$

The probability the sample mean is less than or equal to $6 lbs$ is:

$$P(\bar{x} < 6) = P(z < -3.65) = 0.000131$$

That is, if smoking during pregnancy actually does still lead to an average birth weight of 7 pounds, there was only a 0.000131 (or 0.0131%) chance of getting a sample mean as low as six or lower. This is an extremely unlikely event if the assumption is true. Therefore it is likely the assumption is not true.

Statistical Hypotheses

- A **hypothesis** is a claim or statement about a property of a population.
  - Example: The population mean for systolic blood pressure is 120.
- A **hypothesis test** (or **test of significance**) is a standard procedure for testing a claim about a property of a population.
- Recall the example about birth weights with mothers who smoked during pregnancy.
  - Hypothesis: Smoking during pregnancy leads to an average birth weight of 7 pounds (the same as with mothers who do not smoke).

Statistical Hypotheses

- A **hypothesis** is a claim or statement about a property of a population.
  - Example: The population mean for systolic blood pressure is 120.
- A **hypothesis test** (or **test of significance**) is a standard procedure for testing a claim about a property of a population.
- Recall the example about birth weights with mothers who smoked during pregnancy.
  - Hypothesis: Smoking during pregnancy leads to an average birth weight of 7 pounds (the same as with mothers who do not smoke).

Statistical Hypotheses

- A **hypothesis** is a claim or statement about a property of a population.
  - Example: The population mean for systolic blood pressure is 120.
- A **hypothesis test** (or **test of significance**) is a standard procedure for testing a claim about a property of a population.
- Recall the example about birth weights with mothers who smoked during pregnancy.
  - Hypothesis: Smoking during pregnancy leads to an average birth weight of 7 pounds (the same as with mothers who do not smoke).

Statistical Hypotheses

- A **hypothesis** is a claim or statement about a property of a population.
  - Example: The population mean for systolic blood pressure is 120.
- A **hypothesis test** (or **test of significance**) is a standard procedure for testing a claim about a property of a population.
- Recall the example about birth weights with mothers who smoked during pregnancy.
  - Hypothesis: Smoking during pregnancy leads to an average birth weight of 7 pounds (the same as with mothers who do not smoke).

Statistical Hypotheses

- A **hypothesis** is a claim or statement about a property of a population.
  - Example: The population mean for systolic blood pressure is 120.
- A **hypothesis test** (or **test of significance**) is a standard procedure for testing a claim about a property of a population.
- Recall the example about birth weights with mothers who smoked during pregnancy.
  - Hypothesis: Smoking during pregnancy leads to an average birth weight of 7 pounds (the same as with mothers who do not smoke).

Null and Alternative Hypotheses

- The **null hypothesis** is a statement that the value of a population parameter (such as the population mean) *is equal to* some claimed value.
  - H_0: $\mu = 7$.
- The **alternative hypothesis** is an alternative to the null hypothesis; a statement that says a parameter differs from the value given in the null hypothesis.
  - H_a: $\mu < 7$.
  - H_a: $\mu > 7$.
  - H_a: $\mu \neq 7$.
- In hypothesis testing, assume the null hypothesis is true until there is strong statistical evidence to suggest the alternative hypothesis.
- Similar to an "innocent until proven guilty" policy.

Null and Alternative Hypotheses

- The **null hypothesis** is a statement that the value of a population parameter (such as the population mean) *is equal to* some claimed value.
  - H_0: $\mu = 7$.
- The **alternative hypothesis** is an alternative to the null hypothesis; a statement that says a parameter differs from the value given in the null hypothesis.
  - H_a: $\mu < 7$.
  - H_a: $\mu > 7$.
  - H_a: $\mu \neq 7$.
- In hypothesis testing, assume the null hypothesis is true until there is strong statistical evidence to suggest the alternative hypothesis.
- Similar to an "innocent until proven guilty" policy.

Null and Alternative Hypotheses

- The **null hypothesis** is a statement that the value of a population parameter (such as the population mean) *is equal to* some claimed value.
  - H_0: $\mu = 7$.
- The **alternative hypothesis** is an alternative to the null hypothesis; a statement that says a parameter differs from the value given in the null hypothesis.
  - H_a: $\mu < 7$.
  - H_a: $\mu > 7$.
  - H_a: $\mu \neq 7$.
- In hypothesis testing, assume the null hypothesis is true until there is strong statistical evidence to suggest the alternative hypothesis.
- Similar to an "innocent until proven guilty" policy.

Null and Alternative Hypotheses

- The **null hypothesis** is a statement that the value of a population parameter (such as the population mean) *is equal to* some claimed value.
  - H_0: $\mu = 7$.
- The **alternative hypothesis** is an alternative to the null hypothesis; a statement that says a parameter differs from the value given in the null hypothesis.
  - H_a: $\mu < 7$.
  - H_a: $\mu > 7$.
  - H_a: $\mu \neq 7$.
- In hypothesis testing, assume the null hypothesis is true until there is strong statistical evidence to suggest the alternative hypothesis.
- Similar to an "innocent until proven guilty" policy.

Null and Alternative Hypotheses

- The **null hypothesis** is a statement that the value of a population parameter (such as the population mean) *is equal to* some claimed value.
  - H_0: $\mu = 7$.
- The **alternative hypothesis** is an alternative to the null hypothesis; a statement that says a parameter differs from the value given in the null hypothesis.
  - H_a: $\mu < 7$.
  - H_a: $\mu > 7$.
  - H_a: $\mu \neq 7$.
- In hypothesis testing, assume the null hypothesis is true until there is strong statistical evidence to suggest the alternative hypothesis.
- Similar to an "innocent until proven guilty" policy.

Null and Alternative Hypotheses

- The **null hypothesis** is a statement that the value of a population parameter (such as the population mean) *is equal to* some claimed value.
  - H_0: $\mu = 7$.
- The **alternative hypothesis** is an alternative to the null hypothesis; a statement that says a parameter differs from the value given in the null hypothesis.
  - H_a: $\mu < 7$.
  - H_a: $\mu > 7$.
  - H_a: $\mu \neq 7$.
- In hypothesis testing, assume the null hypothesis is true until there is strong statistical evidence to suggest the alternative hypothesis.
- Similar to an "innocent until proven guilty" policy.

Null and Alternative Hypotheses

- The **null hypothesis** is a statement that the value of a population parameter (such as the population mean) *is equal to* some claimed value.
  - H_0: $\mu = 7$.
- The **alternative hypothesis** is an alternative to the null hypothesis; a statement that says a parameter differs from the value given in the null hypothesis.
  - H_a: $\mu < 7$.
  - H_a: $\mu > 7$.
  - H_a: $\mu \neq 7$.
- In hypothesis testing, assume the null hypothesis is true until there is strong statistical evidence to suggest the alternative hypothesis.
- Similar to an "innocent until proven guilty" policy.

Null and Alternative Hypotheses

- The **null hypothesis** is a statement that the value of a population parameter (such as the population mean) *is equal to* some claimed value.
  - H_0: $\mu = 7$.
- The **alternative hypothesis** is an alternative to the null hypothesis; a statement that says a parameter differs from the value given in the null hypothesis.
  - H_a: $\mu < 7$.
  - H_a: $\mu > 7$.
  - H_a: $\mu \neq 7$.
- In hypothesis testing, assume the null hypothesis is true until there is strong statistical evidence to suggest the alternative hypothesis.
- Similar to an "innocent until proven guilty" policy.

Hypothesis tests

- (Many) hypothesis tests are all the same:

$$z \text{ or } t = \frac{\text{sample statistic} - \text{null hypothesis value}}{\text{standard deviation of the sampling distribution}}$$

- Example: hypothesis testing about μ:
  - Sample statistic $= \bar{x}$.
  - Standard deviation of the sampling distribution of $\bar{x}$:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Hypothesis tests

- (Many) hypothesis tests are all the same:

$$z \text{ or } t = \frac{\text{sample statistic} - \text{null hypothesis value}}{\text{standard deviation of the sampling distribution}}$$

- Example: hypothesis testing about μ:
  - Sample statistic $= \bar{x}$.
  - Standard deviation of the sampling distribution of $\bar{x}$:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Hypothesis tests

- (Many) hypothesis tests are all the same:

$$z \text{ or } t = \frac{\text{sample statistic} - \text{null hypothesis value}}{\text{standard deviation of the sampling distribution}}$$

- Example: hypothesis testing about μ:
  - Sample statistic $= \bar{x}$.
  - Standard deviation of the sampling distribution of $\bar{x}$:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Hypothesis tests

- (Many) hypothesis tests are all the same:

$$z \text{ or } t = \frac{\text{sample statistic} - \text{null hypothesis value}}{\text{standard deviation of the sampling distribution}}$$

- Example: hypothesis testing about μ:
  - Sample statistic $= \bar{x}$.
  - Standard deviation of the sampling distribution of $\bar{x}$:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

P-values

- The P-value of the test statistic, is the area of the sampling distribution from the sample result in the direction of the alternative hypothesis.
- Interpretation: If the null hypothesis is correct, than the p-value is the probability of obtaining a sample that yielded your statistic, or a statistic that provides even stronger evidence against the null hypothesis.
- The p-value is therefore a measure of *statistical significance*.
  - If p-values are very small, there is strong statistical evidence in favor of the alternative hypothesis.
  - If p-values are large, there is insignificant statistical evidence. When large, you fail to reject the null hypothesis.
- Best practice is writing research: report the p-value. Different readers may have different opinions about how small a p-value should be before saying your results are statistically significant.

P-values

- The P-value of the test statistic, is the area of the sampling distribution from the sample result in the direction of the alternative hypothesis.
- Interpretation: If the null hypothesis is correct, than the p-value is the probability of obtaining a sample that yielded your statistic, or a statistic that provides even stronger evidence against the null hypothesis.
- The p-value is therefore a measure of *statistical significance*.
  - If p-values are very small, there is strong statistical evidence in favor of the alternative hypothesis.
  - If p-values are large, there is insignificant statistical evidence. When large, you fail to reject the null hypothesis.
- Best practice is writing research: report the p-value. Different readers may have different opinions about how small a p-value should be before saying your results are statistically significant.

P-values

- The P-value of the test statistic, is the area of the sampling distribution from the sample result in the direction of the alternative hypothesis.
- Interpretation: If the null hypothesis is correct, than the p-value is the probability of obtaining a sample that yielded your statistic, or a statistic that provides even stronger evidence against the null hypothesis.
- The p-value is therefore a measure of *statistical significance*.
  - If p-values are very small, there is strong statistical evidence in favor of the alternative hypothesis.
  - If p-values are large, there is insignificant statistical evidence. When large, you fail to reject the null hypothesis.
- Best practice is writing research: report the p-value. Different readers may have different opinions about how small a p-value should be before saying your results are statistically significant.

P-values

- The P-value of the test statistic, is the area of the sampling distribution from the sample result in the direction of the alternative hypothesis.
- Interpretation: If the null hypothesis is correct, than the p-value is the probability of obtaining a sample that yielded your statistic, or a statistic that provides even stronger evidence against the null hypothesis.
- The p-value is therefore a measure of *statistical significance*.
  - If p-values are very small, there is strong statistical evidence in favor of the alternative hypothesis.
  - If p-values are large, there is insignificant statistical evidence. When large, you fail to reject the null hypothesis.
- Best practice is writing research: report the p-value. Different readers may have different opinions about how small a p-value should be before saying your results are statistically significant.

P-values

- The P-value of the test statistic, is the area of the sampling distribution from the sample result in the direction of the alternative hypothesis.
- Interpretation: If the null hypothesis is correct, than the p-value is the probability of obtaining a sample that yielded your statistic, or a statistic that provides even stronger evidence against the null hypothesis.
- The p-value is therefore a measure of *statistical significance*.
  - If p-values are very small, there is strong statistical evidence in favor of the alternative hypothesis.
  - If p-values are large, there is insignificant statistical evidence. When large, you fail to reject the null hypothesis.
- Best practice is writing research: report the p-value. Different readers may have different opinions about how small a p-value should be before saying your results are statistically significant.

P-values

- The P-value of the test statistic, is the area of the sampling distribution from the sample result in the direction of the alternative hypothesis.
- Interpretation: If the null hypothesis is correct, than the p-value is the probability of obtaining a sample that yielded your statistic, or a statistic that provides even stronger evidence against the null hypothesis.
- The p-value is therefore a measure of *statistical significance*.
  - If p-values are very small, there is strong statistical evidence in favor of the alternative hypothesis.
  - If p-values are large, there is insignificant statistical evidence. When large, you fail to reject the null hypothesis.
- Best practice is writing research: report the p-value. Different readers may have different opinions about how small a p-value should be before saying your results are statistically significant.

Types of Data

- Nominal data: consists of categories that cannot be ordered in a meaningful way.
- Ordinal data: order is meaningful, but not the distances between data values.
  - Excellent, Very good, Good, Poor, Very poor.
- Interval data: order is meaningful, *and* distances are meaningful. However, there is *no natural zero*.
  - Examples: temperature, time.
- Ratio data: order, differences, and zero are all meaningful.
  - Examples: weight, prices, speed.

Types of Data

- Nominal data: consists of categories that cannot be ordered in a meaningful way.
- Ordinal data: order is meaningful, but not the distances between data values.
  - Excellent, Very good, Good, Poor, Very poor.
- Interval data: order is meaningful, *and* distances are meaningful. However, there is *no natural zero*.
  - Examples: temperature, time.
- Ratio data: order, differences, and zero are all meaningful.
  - Examples: weight, prices, speed.

Types of Data

- Nominal data: consists of categories that cannot be ordered in a meaningful way.
- Ordinal data: order is meaningful, but not the distances between data values.
  - Excellent, Very good, Good, Poor, Very poor.
- Interval data: order is meaningful, *and* distances are meaningful. However, there is *no natural zero*.
  - Examples: temperature, time.
- Ratio data: order, differences, and zero are all meaningful.
  - Examples: weight, prices, speed.

Types of Data

- Nominal data: consists of categories that cannot be ordered in a meaningful way.
- Ordinal data: order is meaningful, but not the distances between data values.
    - Excellent, Very good, Good, Poor, Very poor.
- Interval data: order is meaningful, *and* distances are meaningful. However, there is *no natural zero*.
    - Examples: temperature, time.
- Ratio data: order, differences, and zero are all meaningful.
    - Examples: weight, prices, speed.

Types of Data

- Nominal data: consists of categories that cannot be ordered in a meaningful way.
- Ordinal data: order is meaningful, but not the distances between data values.
  - Excellent, Very good, Good, Poor, Very poor.
- Interval data: order is meaningful, *and* distances are meaningful. However, there is *no natural zero*.
  - Examples: temperature, time.
- Ratio data: order, differences, and zero are all meaningful.
  - Examples: weight, prices, speed.

Types of Data

- Nominal data: consists of categories that cannot be ordered in a meaningful way.
- Ordinal data: order is meaningful, but not the distances between data values.
  - Excellent, Very good, Good, Poor, Very poor.
- Interval data: order is meaningful, *and* distances are meaningful. However, there is *no natural zero*.
  - Examples: temperature, time.
- Ratio data: order, differences, and zero are all meaningful.
  - Examples: weight, prices, speed.

Types of Data

- Nominal data: consists of categories that cannot be ordered in a meaningful way.
- Ordinal data: order is meaningful, but not the distances between data values.
  - Excellent, Very good, Good, Poor, Very poor.
- Interval data: order is meaningful, *and* distances are meaningful. However, there is *no natural zero*.
  - Examples: temperature, time.
- Ratio data: order, differences, and zero are all meaningful.
  - Examples: weight, prices, speed.

Types of Tests

- Different types of data require different statistical methods.
- Why? With interval data and below, operations like addition, subtraction, multiplication, and division are *meaningless!*
- Parametric statistics:
  - Typically take advantage of central limit theorem (imposes requirements on probability distributions)
  - Appropriate only for interval and ratio data.
  - More **powerful** than nonparametric methods.
- Nonparametric statistics:
  - Do not require assumptions concerning the probability distribution for the population.
  - There are many methods appropriate for ordinal data, some methods appropriate for nominal data.
  - Computations typically make use of data's *ranks* instead of actual data.

Types of Tests

- Different types of data require different statistical methods.
- Why? With interval data and below, operations like addition, subtraction, multiplication, and division are *meaningless!*
- Parametric statistics:
  - Typically take advantage of central limit theorem (imposes requirements on probability distributions)
  - Appropriate only for interval and ratio data.
  - More **powerful** than nonparametric methods.
- Nonparametric statistics:
  - Do not require assumptions concerning the probability distribution for the population.
  - There are many methods appropriate for ordinal data, some methods appropriate for nominal data.
  - Computations typically make use of data's *ranks* instead of actual data.

Types of Tests

- Different types of data require different statistical methods.
- Why? With interval data and below, operations like addition, subtraction, multiplication, and division are *meaningless!*
- Parametric statistics:
  - Typically take advantage of central limit theorem (imposes requirements on probability distributions)
  - Appropriate only for interval and ratio data.
  - More **powerful** than nonparametric methods.
- Nonparametric statistics:
  - Do not require assumptions concerning the probability distribution for the population.
  - There are many methods appropriate for ordinal data, some methods appropriate for nominal data.
  - Computations typically make use of data's *ranks* instead of actual data.

Types of Tests

- Different types of data require different statistical methods.
- Why? With interval data and below, operations like addition, subtraction, multiplication, and division are *meaningless!*
- Parametric statistics:
  - Typically take advantage of central limit theorem (imposes requirements on probability distributions)
  - Appropriate only for interval and ratio data.
  - More **powerful** than nonparametric methods.
- Nonparametric statistics:
  - Do not require assumptions concerning the probability distribution for the population.
  - There are many methods appropriate for ordinal data, some methods appropriate for nominal data.
  - Computations typically make use of data's *ranks* instead of actual data.

Types of Tests

- Different types of data require different statistical methods.
- Why? With interval data and below, operations like addition, subtraction, multiplication, and division are *meaningless!*
- Parametric statistics:
  - Typically take advantage of central limit theorem (imposes requirements on probability distributions)
  - Appropriate only for interval and ratio data.
  - More **powerful** than nonparametric methods.
- Nonparametric statistics:
  - Do not require assumptions concerning the probability distribution for the population.
  - There are many methods appropriate for ordinal data, some methods appropriate for nominal data.
  - Computations typically make use of data's *ranks* instead of actual data.

Types of Tests

- Different types of data require different statistical methods.
- Why? With interval data and below, operations like addition, subtraction, multiplication, and division are *meaningless!*
- Parametric statistics:
    - Typically take advantage of central limit theorem (imposes requirements on probability distributions)
    - Appropriate only for interval and ratio data.
    - More **powerful** than nonparametric methods.
- Nonparametric statistics:
    - Do not require assumptions concerning the probability distribution for the population.
    - There are many methods appropriate for ordinal data, some methods appropriate for nominal data.
    - Computations typically make use of data's *ranks* instead of actual data.

Types of Tests

- Different types of data require different statistical methods.
- Why? With interval data and below, operations like addition, subtraction, multiplication, and division are *meaningless!*
- Parametric statistics:
  - Typically take advantage of central limit theorem (imposes requirements on probability distributions)
  - Appropriate only for interval and ratio data.
  - More **powerful** than nonparametric methods.
- Nonparametric statistics:
  - Do not require assumptions concerning the probability distribution for the population.
  - There are many methods appropriate for ordinal data, some methods appropriate for nominal data.
  - Computations typically make use of data's *ranks* instead of actual data.

Types of Tests

- Different types of data require different statistical methods.
- Why? With interval data and below, operations like addition, subtraction, multiplication, and division are *meaningless!*
- Parametric statistics:
  - Typically take advantage of central limit theorem (imposes requirements on probability distributions)
  - Appropriate only for interval and ratio data.
  - More **powerful** than nonparametric methods.
- Nonparametric statistics:
  - Do not require assumptions concerning the probability distribution for the population.
  - There are many methods appropriate for ordinal data, some methods appropriate for nominal data.
  - Computations typically make use of data's *ranks* instead of actual data.

Types of Tests

- Different types of data require different statistical methods.
- Why? With interval data and below, operations like addition, subtraction, multiplication, and division are *meaningless!*
- Parametric statistics:
  - Typically take advantage of central limit theorem (imposes requirements on probability distributions)
  - Appropriate only for interval and ratio data.
  - More **powerful** than nonparametric methods.
- Nonparametric statistics:
  - Do not require assumptions concerning the probability distribution for the population.
  - There are many methods appropriate for ordinal data, some methods appropriate for nominal data.
  - Computations typically make use of data's *ranks* instead of actual data.

Types of Tests

- Different types of data require different statistical methods.
- Why? With interval data and below, operations like addition, subtraction, multiplication, and division are *meaningless!*
- Parametric statistics:
  - Typically take advantage of central limit theorem (imposes requirements on probability distributions)
  - Appropriate only for interval and ratio data.
  - More **powerful** than nonparametric methods.
- Nonparametric statistics:
  - Do not require assumptions concerning the probability distribution for the population.
  - There are many methods appropriate for ordinal data, some methods appropriate for nominal data.
  - Computations typically make use of data's *ranks* instead of actual data.

Single Mean T-Test

- Test whether the population mean is equal or different to some value.
- Uses the sample mean its statistic.
- Why T-test instead of Z-test?
- Parametric test that depends on results from Central Limit Theorem.
- Hypotheses
  - Null: The population mean is equal to some specified value.
  - Alternative: The population mean is [greater/less/different] than the value in the null.

Single Mean T-Test

- Test whether the population mean is equal or different to some value.
- Uses the sample mean its statistic.
- Why T-test instead of Z-test?
- Parametric test that depends on results from Central Limit Theorem.
- Hypotheses
  - Null: The population mean is equal to some specified value.
  - Alternative: The population mean is [greater/less/different] than the value in the null.

Single Mean T-Test

- Test whether the population mean is equal or different to some value.
- Uses the sample mean its statistic.
- Why T-test instead of Z-test?
- Parametric test that depends on results from Central Limit Theorem.
- Hypotheses
  - Null: The population mean is equal to some specified value.
  - Alternative: The population mean is [greater/less/different] than the value in the null.

Single Mean T-Test

- Test whether the population mean is equal or different to some value.
- Uses the sample mean its statistic.
- Why T-test instead of Z-test?
- Parametric test that depends on results from Central Limit Theorem.
- Hypotheses
  - Null: The population mean is equal to some specified value.
  - Alternative: The population mean is [greater/less/different] than the value in the null.

Single Mean T-Test

- Test whether the population mean is equal or different to some value.
- Uses the sample mean its statistic.
- Why T-test instead of Z-test?
- Parametric test that depends on results from Central Limit Theorem.
- Hypotheses
  - Null: The population mean is equal to some specified value.
  - Alternative: The population mean is [greater/less/different] than the value in the null.

Single Mean T-Test

- Test whether the population mean is equal or different to some value.
- Uses the sample mean its statistic.
- Why T-test instead of Z-test?
- Parametric test that depends on results from Central Limit Theorem.
- Hypotheses
  - Null: The population mean is equal to some specified value.
  - Alternative: The population mean is [greater/less/different] than the value in the null.

Single Mean T-Test

- Test whether the population mean is equal or different to some value.
- Uses the sample mean its statistic.
- Why T-test instead of Z-test?
- Parametric test that depends on results from Central Limit Theorem.
- Hypotheses
    - Null: The population mean is equal to some specified value.
    - Alternative: The population mean is [greater/less/different] than the value in the null.

Example: Public School Spending

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Download dataset `eduspending.sav`.
- Conduct the following exercises:
  - Show some descriptive statistics for teacher pay and expenditure per pupil.
  - Is there statistical evidence that teachers make less than $25,000 per year?
  - Is there statistical evidence that expenditure per pupil is more than $3,500?

Example: Public School Spending

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Download dataset `eduspending.sav`.
- Conduct the following exercises:
  - Show some descriptive statistics for teacher pay and expenditure per pupil.
  - Is there statistical evidence that teachers make less than $25,000 per year?
  - Is there statistical evidence that expenditure per pupil is more than $3,500?

Example: Public School Spending

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Download dataset `eduspending.sav`.
- Conduct the following exercises:
    - Show some descriptive statistics for teacher pay and expenditure per pupil.
    - Is there statistical evidence that teachers make less than $25,000 per year?
    - Is there statistical evidence that expenditure per pupil is more than $3,500?

Example: Public School Spending

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Download dataset `eduspending.sav`.
- Conduct the following exercises:
  - Show some descriptive statistics for teacher pay and expenditure per pupil.
  - Is there statistical evidence that teachers make less than $25,000 per year?
  - Is there statistical evidence that expenditure per pupil is more than $3,500?

Example: Public School Spending

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Download dataset `eduspending.sav`.
- Conduct the following exercises:
  - Show some descriptive statistics for teacher pay and expenditure per pupil.
  - Is there statistical evidence that teachers make less than $25,000 per year?
  - Is there statistical evidence that expenditure per pupil is more than $3,500?

Example: Public School Spending

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Download dataset `eduspending.sav`.
- Conduct the following exercises:
  - Show some descriptive statistics for teacher pay and expenditure per pupil.
  - Is there statistical evidence that teachers make less than $25,000 per year?
  - Is there statistical evidence that expenditure per pupil is more than $3,500?

Single Proportion T-Test

- **Proportion:** Percentage of times some characteristic occurs.
- Example: percentage of consumers of soda who prefer Pepsi over Coke.

$$\text{Sample proportion} = \frac{\text{Number of items that has characteristic}}{\text{sample size}}$$

Single Proportion T-Test

- **Proportion:** Percentage of times some characteristic occurs.
- Example: percentage of consumers of soda who prefer Pepsi over Coke.

$$\text{Sample proportion} = \frac{\text{Number of items that has characteristic}}{\text{sample size}}$$

Single Proportion T-Test

- **Proportion:** Percentage of times some characteristic occurs.
- Example: percentage of consumers of soda who prefer Pepsi over Coke.

$$\text{Sample proportion} = \frac{\text{Number of items that has characteristic}}{\text{sample size}}$$

Example: Economic Outlook

- Data from Montana residents in 1992 concerning their outlook for the economy.
- All data is ordinal or nominal:
  - AGE = 1 under 35, 2 35-54, 3 55 and over
  - SEX = 0 male, 1 female
  - INC = yearly income: 1 under $20K, 2 20-35$K, 3 over $35K
  - POL = 1 Democrat, 2 Independent, 3 Republican
  - AREA = 1 Western, 2 Northeastern, 3 Southeastern Montana
  - FIN = Financial status 1 worse, 2 same, 3 better than a year ago
  - STAT = 0, State economic outlook better, 1 not better than a year ago
- Do the majority of Montana residents feel their financial status is the same or better than one year ago?
- Do the majority of Montana residents have a more positive economic outlook than one year ago?

Example: Economic Outlook

- Data from Montana residents in 1992 concerning their outlook for the economy.
- All data is ordinal or nominal:
  - AGE = 1 under 35, 2 35-54, 3 55 and over
  - SEX = 0 male, 1 female
  - INC = yearly income: 1 under $20K, 2 20-35$K, 3 over $35K
  - POL = 1 Democrat, 2 Independent, 3 Republican
  - AREA = 1 Western, 2 Northeastern, 3 Southeastern Montana
  - FIN = Financial status 1 worse, 2 same, 3 better than a year ago
  - STAT = 0, State economic outlook better, 1 not better than a year ago
- Do the majority of Montana residents feel their financial status is the same or better than one year ago?
- Do the majority of Montana residents have a more positive economic outlook than one year ago?

Example: Economic Outlook

- Data from Montana residents in 1992 concerning their outlook for the economy.
- All data is ordinal or nominal:
  - AGE = 1 under 35, 2 35-54, 3 55 and over
  - SEX = 0 male, 1 female
  - INC = yearly income: 1 under $20K, 2 20-35$K, 3 over $35K
  - POL = 1 Democrat, 2 Independent, 3 Republican
  - AREA = 1 Western, 2 Northeastern, 3 Southeastern Montana
  - FIN = Financial status 1 worse, 2 same, 3 better than a year ago
  - STAT = 0, State economic outlook better, 1 not better than a year ago
- Do the majority of Montana residents feel their financial status is the same or better than one year ago?
- Do the majority of Montana residents have a more positive economic outlook than one year ago?

Example: Economic Outlook

- Data from Montana residents in 1992 concerning their outlook for the economy.
- All data is ordinal or nominal:
  - AGE = 1 under 35, 2 35-54, 3 55 and over
  - SEX = 0 male, 1 female
  - INC = yearly income: 1 under $20K, 2 20-35$K, 3 over $35K
  - POL = 1 Democrat, 2 Independent, 3 Republican
  - AREA = 1 Western, 2 Northeastern, 3 Southeastern Montana
  - FIN = Financial status 1 worse, 2 same, 3 better than a year ago
  - STAT = 0, State economic outlook better, 1 not better than a year ago
- Do the majority of Montana residents feel their financial status is the same or better than one year ago?
- Do the majority of Montana residents have a more positive economic outlook than one year ago?

Single Median Nonparametric Test

- Why?
  - Ordinal data: cannot compute sample means (they are meaningless), only median is meaningful.
  - Small sample size and you are not sure the population is not normal.
- Single-Sample Wilcoxon Signed Rank Test.
- Hypotheses
  - Null: The population median is equal to some specified value.
  - Alternative: The population median is different than the value in the null.

Single Median Nonparametric Test

- Why?
  - Ordinal data: cannot compute sample means (they are meaningless), only median is meaningful.
  - Small sample size and you are not sure the population is not normal.
- Single-Sample Wilcoxon Signed Rank Test.
- Hypotheses
  - Null: The population median is equal to some specified value.
  - Alternative: The population median is different than the value in the null.

Single Median Nonparametric Test

- Why?
  - Ordinal data: cannot compute sample means (they are meaningless), only median is meaningful.
  - Small sample size and you are not sure the population is not normal.
- Single-Sample Wilcoxon Signed Rank Test.
- Hypotheses
  - Null: The population median is equal to some specified value.
  - Alternative: The population median is different than the value in the null.

Single Median Nonparametric Test

- Why?
  - Ordinal data: cannot compute sample means (they are meaningless), only median is meaningful.
  - Small sample size and you are not sure the population is not normal.
- Single-Sample Wilcoxon Signed Rank Test.
- Hypotheses
  - Null: The population median is equal to some specified value.
  - Alternative: The population median is different than the value in the null.

Single Median Nonparametric Test

- Why?
  - Ordinal data: cannot compute sample means (they are meaningless), only median is meaningful.
  - Small sample size and you are not sure the population is not normal.
- Single-Sample Wilcoxon Signed Rank Test.
- Hypotheses
  - Null: The population median is equal to some specified value.
  - Alternative: The population median is different than the value in the null.

Single Median Nonparametric Test

- Why?
  - Ordinal data: cannot compute sample means (they are meaningless), only median is meaningful.
  - Small sample size and you are not sure the population is not normal.
- Single-Sample Wilcoxon Signed Rank Test.
- Hypotheses
  - Null: The population median is equal to some specified value.
  - Alternative: The population median is different than the value in the null.

Single Median Nonparametric Test

- Why?
  - Ordinal data: cannot compute sample means (they are meaningless), only median is meaningful.
  - Small sample size and you are not sure the population is not normal.
- Single-Sample Wilcoxon Signed Rank Test.
- Hypotheses
  - Null: The population median is equal to some specified value.
  - Alternative: The population median is different than the value in the null.

Example: Attitudes Grade School Kids

- Dataset: 438 students in grades 4 through 6 were sampled from three school districts in Michigan. Students ranked from 1 (most important) to 5 (least important) how important grades, sports, being good looking, and having lots of money were to each of them.
- Open dataset `gradschools.sav`. Choose second worksheet, titled `Data`.
- Answer some of these questions:
  - Is the median importance for grades is greater than 3?
  - Is the median importance for money less than 3?

Example: Attitudes Grade School Kids

- Dataset: 438 students in grades 4 through 6 were sampled from three school districts in Michigan. Students ranked from 1 (most important) to 5 (least important) how important grades, sports, being good looking, and having lots of money were to each of them.
- Open dataset `gradschools.sav`. Choose second worksheet, titled `Data`.
- Answer some of these questions:
  - Is the median importance for grades is greater than 3?
  - Is the median importance for money less than 3?

Example: Attitudes Grade School Kids

- Dataset: 438 students in grades 4 through 6 were sampled from three school districts in Michigan. Students ranked from 1 (most important) to 5 (least important) how important grades, sports, being good looking, and having lots of money were to each of them.
- Open dataset `gradschools.sav`. Choose second worksheet, titled `Data`.
- Answer some of these questions:
  - Is the median importance for grades is greater than 3?
  - Is the median importance for money less than 3?

Example: Attitudes Grade School Kids

- Dataset: 438 students in grades 4 through 6 were sampled from three school districts in Michigan. Students ranked from 1 (most important) to 5 (least important) how important grades, sports, being good looking, and having lots of money were to each of them.
- Open dataset `gradschools.sav`. Choose second worksheet, titled `Data`.
- Answer some of these questions:
  - Is the median importance for grades is greater than 3?
  - Is the median importance for money less than 3?

Example: Attitudes Grade School Kids

- Dataset: 438 students in grades 4 through 6 were sampled from three school districts in Michigan. Students ranked from 1 (most important) to 5 (least important) how important grades, sports, being good looking, and having lots of money were to each of them.
- Open dataset `gradschools.sav`. Choose second worksheet, titled `Data`.
- Answer some of these questions:
  - Is the median importance for grades is greater than 3?
  - Is the median importance for money less than 3?

Difference in Means (Independent Samples)

- Suppose you want to know whether the mean from one population is larger than the mean for another.
- Examples:
  - Compare sales volume for stores that advertise versus those that do not.
  - Compare production volume for employees that have completed some type of training versus those who have not.
- Statistic: Difference in the sample means $(\bar{x}_1 - \bar{x}_2)$.

Difference in Means (Independent Samples)

- Suppose you want to know whether the mean from one population is larger than the mean for another.
- Examples:
  - Compare sales volume for stores that advertise versus those that do not.
  - Compare production volume for employees that have completed some type of training versus those who have not.
- Statistic: Difference in the sample means $(\bar{x}_1 - \bar{x}_2)$.

Difference in Means (Independent Samples)

- Suppose you want to know whether the mean from one population is larger than the mean for another.
- Examples:
  - Compare sales volume for stores that advertise versus those that do not.
  - Compare production volume for employees that have completed some type of training versus those who have not.
- Statistic: Difference in the sample means $(\bar{x}_1 - \bar{x}_2)$.

Difference in Means (Independent Samples)

- Suppose you want to know whether the mean from one population is larger than the mean for another.
- Examples:
  - Compare sales volume for stores that advertise versus those that do not.
  - Compare production volume for employees that have completed some type of training versus those who have not.
- Statistic: Difference in the sample means $(\bar{x}_1 - \bar{x}_2)$.

Difference in Means (Independent Samples)

- Suppose you want to know whether the mean from one population is larger than the mean for another.
- Examples:
  - Compare sales volume for stores that advertise versus those that do not.
  - Compare production volume for employees that have completed some type of training versus those who have not.
- Statistic: Difference in the sample means $(\bar{x}_1 - \bar{x}_2)$.

Independent Samples T-Test

- Hypotheses:
  - Null hypothesis: the difference between the two means is zero.
  - Alternative hypothesis: the difference is [above/below/not equal] to zero.
- Different ways to compute the test depending on whether...
  - the variance in the two populations is the same (more powerful test), or...
  - the variance of the two populations is different.
  - To guide you, SPSS also reports Levene's test for equality of variance (Null - variances are the same).

Independent Samples T-Test

- Hypotheses:
  - Null hypothesis: the difference between the two means is zero.
  - Alternative hypothesis: the difference is [above/below/not equal] to zero.
- Different ways to compute the test depending on whether...
  - the variance in the two populations is the same (more powerful test), or...
  - the variance of the two populations is different.
  - To guide you, SPSS also reports Levene's test for equality of variance (Null - variances are the same).

Independent Samples T-Test

- Hypotheses:
  - Null hypothesis: the difference between the two means is zero.
  - Alternative hypothesis: the difference is [above/below/not equal] to zero.
- Different ways to compute the test depending on whether...
  - the variance in the two populations is the same (more powerful test), or...
  - the variance of the two populations is different.
  - To guide you, SPSS also reports Levene's test for equality of variance (Null - variances are the same).

Independent Samples T-Test

- Hypotheses:
  - Null hypothesis: the difference between the two means is zero.
  - Alternative hypothesis: the difference is [above/below/not equal] to zero.
- Different ways to compute the test depending on whether...
  - the variance in the two populations is the same (more powerful test), or...
  - the variance of the two populations is different.
  - To guide you, SPSS also reports Levene's test for equality of variance (Null - variances are the same).

Independent Samples T-Test

- Hypotheses:
  - Null hypothesis: the difference between the two means is zero.
  - Alternative hypothesis: the difference is [above/below/not equal] to zero.
- Different ways to compute the test depending on whether...
  - the variance in the two populations is the same (more powerful test), or...
  - the variance of the two populations is different.
  - To guide you, SPSS also reports Levene's test for equality of variance (Null - variances are the same).

Independent Samples T-Test

- Hypotheses:
  - Null hypothesis: the difference between the two means is zero.
  - Alternative hypothesis: the difference is [above/below/not equal] to zero.
- Different ways to compute the test depending on whether...
  - the variance in the two populations is the same (more powerful test), or...
  - the variance of the two populations is different.
  - To guide you, SPSS also reports Levene's test for equality of variance (Null - variances are the same).

Independent Samples T-Test

- Hypotheses:
  - Null hypothesis: the difference between the two means is zero.
  - Alternative hypothesis: the difference is [above/below/not equal] to zero.
- Different ways to compute the test depending on whether...
  - the variance in the two populations is the same (more powerful test), or...
  - the variance of the two populations is different.
  - To guide you, SPSS also reports Levene's test for equality of variance (Null - variances are the same).

Example

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Test the following hypotheses:
  - Does spending per pupil differ in the North (region 1) and the South (region 2)?
  - Does teacher salary differ in the North and the West (region 3)?
- Do you see any weaknesses in our statistical analysis?

Example

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Test the following hypotheses:
  - Does spending per pupil differ in the North (region 1) and the South (region 2)?
  - Does teacher salary differ in the North and the West (region 3)?
- Do you see any weaknesses in our statistical analysis?

Example

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Test the following hypotheses:
    - Does spending per pupil differ in the North (region 1) and the South (region 2)?
    - Does teacher salary differ in the North and the West (region 3)?
- Do you see any weaknesses in our statistical analysis?

Example

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Test the following hypotheses:
  - Does spending per pupil differ in the North (region 1) and the South (region 2)?
  - Does teacher salary differ in the North and the West (region 3)?
- Do you see any weaknesses in our statistical analysis?

Example

- Dataset: average pay for public school teachers and average public school spending per pupil for each state and the District of Columbia in 1985.
- Test the following hypotheses:
  - Does spending per pupil differ in the North (region 1) and the South (region 2)?
  - Does teacher salary differ in the North and the West (region 3)?
- Do you see any weaknesses in our statistical analysis?

Nonparametric Tests for Differences in Medians

- Mann-Whitney U test: nonparametric test to determine difference in *medians*.
- Assumptions:
  - Samples are independent of one another.
  - The underlying distributions have the same shape (i.e. only the location of the distribution is different).
  - It has been argued that violating the second assumption does not severely change the sampling distribution of the Mann-Whitney U test.
- Null hypothesis: medians for the two populations are the same.
- Alternative hypotheses: medians for the two populations are different.

Nonparametric Tests for Differences in Medians

- Mann-Whitney U test: nonparametric test to determine difference in *medians*.
- Assumptions:
  - Samples are independent of one another.
  - The underlying distributions have the same shape (i.e. only the location of the distribution is different).
  - It has been argued that violating the second assumption does not severely change the sampling distribution of the Mann-Whitney U test.
- Null hypothesis: medians for the two populations are the same.
- Alternative hypotheses: medians for the two populations are different.

Nonparametric Tests for Differences in Medians

- Mann-Whitney U test: nonparametric test to determine difference in *medians*.
- Assumptions:
  - Samples are independent of one another.
  - The underlying distributions have the same shape (i.e. only the location of the distribution is different).
  - It has been argued that violating the second assumption does not severely change the sampling distribution of the Mann-Whitney U test.
- Null hypothesis: medians for the two populations are the same.
- Alternative hypotheses: medians for the two populations are different.

Nonparametric Tests for Differences in Medians

- Mann-Whitney U test: nonparametric test to determine difference in *medians*.
- Assumptions:
  - Samples are independent of one another.
  - The underlying distributions have the same shape (i.e. only the location of the distribution is different).
  - It has been argued that violating the second assumption does not severely change the sampling distribution of the Mann-Whitney U test.
- Null hypothesis: medians for the two populations are the same.
- Alternative hypotheses: medians for the two populations are different.

Nonparametric Tests for Differences in Medians

- Mann-Whitney U test: nonparametric test to determine difference in *medians*.
- Assumptions:
  - Samples are independent of one another.
  - The underlying distributions have the same shape (i.e. only the location of the distribution is different).
  - It has been argued that violating the second assumption does not severely change the sampling distribution of the Mann-Whitney U test.
- Null hypothesis: medians for the two populations are the same.
- Alternative hypotheses: medians for the two populations are different.

Nonparametric Tests for Differences in Medians

- Mann-Whitney U test: nonparametric test to determine difference in *medians*.
- Assumptions:
  - Samples are independent of one another.
  - The underlying distributions have the same shape (i.e. only the location of the distribution is different).
  - It has been argued that violating the second assumption does not severely change the sampling distribution of the Mann-Whitney U test.
- Null hypothesis: medians for the two populations are the same.
- Alternative hypotheses: medians for the two populations are different.

Nonparametric Tests for Differences in Medians

- Mann-Whitney U test: nonparametric test to determine difference in *medians*.
- Assumptions:
  - Samples are independent of one another.
  - The underlying distributions have the same shape (i.e. only the location of the distribution is different).
  - It has been argued that violating the second assumption does not severely change the sampling distribution of the Mann-Whitney U test.
- Null hypothesis: medians for the two populations are the same.
- Alternative hypotheses: medians for the two populations are different.

Dependent Samples - Paired Samples

- Use a **paired sampled test** if the two samples have the same individuals or sampling units.
- Many examples include before/after tests for differences:
  - The Biggest Loser: Compare the weight of people on the show before the season begins and one year after the show concludes.
  - Training session: Are workers more productive 6 months after they attended some training session versus before the training session.
- Examples besides before/after tests for differences:
  - Do students spend more time studying than watching TV?
  - Does the unemployment rate for White/Caucasian differ from the unemployment rate for African Americans (sampling unit = U.S. state).
- These are dependent samples, because you have the same sampling units in each group.

Dependent Samples - Paired Samples

- Use a **paired sampled test** if the two samples have the same individuals or sampling units.
- Many examples include before/after tests for differences:
  - The Biggest Loser: Compare the weight of people on the show before the season begins and one year after the show concludes.
  - Training session: Are workers more productive 6 months after they attended some training session versus before the training session.
- Examples besides before/after tests for differences:
  - Do students spend more time studying than watching TV?
  - Does the unemployment rate for White/Caucasian differ from the unemployment rate for African Americans (sampling unit = U.S. state).
- These are dependent samples, because you have the same sampling units in each group.

Dependent Samples - Paired Samples

- Use a **paired sampled test** if the two samples have the same individuals or sampling units.
- Many examples include before/after tests for differences:
  - The Biggest Loser: Compare the weight of people on the show before the season begins and one year after the show concludes.
  - Training session: Are workers more productive 6 months after they attended some training session versus before the training session.
- Examples besides before/after tests for differences:
  - Do students spend more time studying than watching TV?
  - Does the unemployment rate for White/Caucasian differ from the unemployment rate for African Americans (sampling unit = U.S. state).
- These are dependent samples, because you have the same sampling units in each group.

Dependent Samples - Paired Samples

- Use a **paired sampled test** if the two samples have the same individuals or sampling units.
- Many examples include before/after tests for differences:
  - The Biggest Loser: Compare the weight of people on the show before the season begins and one year after the show concludes.
  - Training session: Are workers more productive 6 months after they attended some training session versus before the training session.
- Examples besides before/after tests for differences:
  - Do students spend more time studying than watching TV?
  - Does the unemployment rate for White/Caucasian differ from the unemployment rate for African Americans (sampling unit = U.S. state).
- These are dependent samples, because you have the same sampling units in each group.

Dependent Samples - Paired Samples

- Use a **paired sampled test** if the two samples have the same individuals or sampling units.
- Many examples include before/after tests for differences:
  - The Biggest Loser: Compare the weight of people on the show before the season begins and one year after the show concludes.
  - Training session: Are workers more productive 6 months after they attended some training session versus before the training session.
- Examples besides before/after tests for differences:
  - Do students spend more time studying than watching TV?
  - Does the unemployment rate for White/Caucasian differ from the unemployment rate for African Americans (sampling unit = U.S. state).
- These are dependent samples, because you have the same sampling units in each group.

Dependent Samples - Paired Samples

- Use a **paired sampled test** if the two samples have the same individuals or sampling units.
- Many examples include before/after tests for differences:
  - The Biggest Loser: Compare the weight of people on the show before the season begins and one year after the show concludes.
  - Training session: Are workers more productive 6 months after they attended some training session versus before the training session.
- Examples besides before/after tests for differences:
  - Do students spend more time studying than watching TV?
  - Does the unemployment rate for White/Caucasian differ from the unemployment rate for African Americans (sampling unit = U.S. state).
- These are dependent samples, because you have the same sampling units in each group.

Dependent Samples - Paired Samples

- Use a **paired sampled test** if the two samples have the same individuals or sampling units.
- Many examples include before/after tests for differences:
  - The Biggest Loser: Compare the weight of people on the show before the season begins and one year after the show concludes.
  - Training session: Are workers more productive 6 months after they attended some training session versus before the training session.
- Examples besides before/after tests for differences:
  - Do students spend more time studying than watching TV?
  - Does the unemployment rate for White/Caucasian differ from the unemployment rate for African Americans (sampling unit = U.S. state).
- These are dependent samples, because you have the same sampling units in each group.

Dependent Samples - Paired Samples

- Use a **paired sampled test** if the two samples have the same individuals or sampling units.
- Many examples include before/after tests for differences:
  - The Biggest Loser: Compare the weight of people on the show before the season begins and one year after the show concludes.
  - Training session: Are workers more productive 6 months after they attended some training session versus before the training session.
- Examples besides before/after tests for differences:
  - Do students spend more time studying than watching TV?
  - Does the unemployment rate for White/Caucasian differ from the unemployment rate for African Americans (sampling unit = U.S. state).
- These are dependent samples, because you have the same sampling units in each group.

Paired Samples Parametric vs Nonparametric

- Parametric test: Paired-samples t-test.
  - Measurement is taken from the sample sampling units (eg: individuals) in each group.
  - Interval/ratio data.
  - Assumptions of CLT must be met.
- Nonparametric test: Wilcoxon Signed Rank Test for Paired Samples
  - Good for *ordinal* and interval/ratio.
  - Good when assumptions of CLT are violated.

Paired Samples Parametric vs Nonparametric

- Parametric test: Paired-samples t-test.
  - Measurement is taken from the sample sampling units (eg: individuals) in each group.
  - Interval/ratio data.
  - Assumptions of CLT must be met.
- Nonparametric test: Wilcoxon Signed Rank Test for Paired Samples
  - Good for *ordinal* and interval/ratio.
  - Good when assumptions of CLT are violated.

Paired Samples Parametric vs Nonparametric

- Parametric test: Paired-samples t-test.
  - Measurement is taken from the sample sampling units (eg: individuals) in each group.
  - Interval/ratio data.
  - Assumptions of CLT must be met.
- Nonparametric test: Wilcoxon Signed Rank Test for Paired Samples
  - Good for *ordinal* and interval/ratio.
  - Good when assumptions of CLT are violated.

Paired Samples Parametric vs Nonparametric

- Parametric test: Paired-samples t-test.
  - Measurement is taken from the sample sampling units (eg: individuals) in each group.
  - Interval/ratio data.
  - Assumptions of CLT must be met.
- Nonparametric test: Wilcoxon Signed Rank Test for Paired Samples
  - Good for *ordinal* and interval/ratio.
  - Good when assumptions of CLT are violated.

Paired Samples Parametric vs Nonparametric

- Parametric test: Paired-samples t-test.
  - Measurement is taken from the sample sampling units (eg: individuals) in each group.
  - Interval/ratio data.
  - Assumptions of CLT must be met.
- Nonparametric test: Wilcoxon Signed Rank Test for Paired Samples
  - Good for *ordinal* and interval/ratio.
  - Good when assumptions of CLT are violated.

Paired Samples Parametric vs Nonparametric

- Parametric test: Paired-samples t-test.
  - Measurement is taken from the sample sampling units (eg: individuals) in each group.
  - Interval/ratio data.
  - Assumptions of CLT must be met.
- Nonparametric test: Wilcoxon Signed Rank Test for Paired Samples
  - Good for *ordinal* and interval/ratio.
  - Good when assumptions of CLT are violated.

Paired Samples Parametric vs Nonparametric

- Parametric test: Paired-samples t-test.
  - Measurement is taken from the sample sampling units (eg: individuals) in each group.
  - Interval/ratio data.
  - Assumptions of CLT must be met.
- Nonparametric test: Wilcoxon Signed Rank Test for Paired Samples
  - Good for *ordinal* and interval/ratio.
  - Good when assumptions of CLT are violated.

Conclusions

- Ideas to keep in mind:
  - What is a sampling distribution? What does it imply about p-values and statistical significance?
  - When it is appropriate to use parametric versus non-parametric methods.
  - Most univariate and bivariate questions have a parametric and non-parametric approach.
- Homework assignment due next week.
- Next: Regression Analysis - looking at more complex relationships between more than 2 variables.

Conclusions

- Ideas to keep in mind:
  - What is a sampling distribution? What does it imply about p-values and statistical significance?
  - When it is appropriate to use parametric versus non-parametric methods.
  - Most univariate and bivariate questions have a parametric and non-parametric approach.
- Homework assignment due next week.
- Next: Regression Analysis - looking at more complex relationships between more than 2 variables.

Conclusions

- Ideas to keep in mind:
  - What is a sampling distribution? What does it imply about p-values and statistical significance?
  - When it is appropriate to use parametric versus non-parametric methods.
  - Most univariate and bivariate questions have a parametric and non-parametric approach.
- Homework assignment due next week.
- Next: Regression Analysis - looking at more complex relationships between more than 2 variables.

Conclusions

- Ideas to keep in mind:
  - What is a sampling distribution? What does it imply about p-values and statistical significance?
  - When it is appropriate to use parametric versus non-parametric methods.
  - Most univariate and bivariate questions have a parametric and non-parametric approach.
- Homework assignment due next week.
- Next: Regression Analysis - looking at more complex relationships between more than 2 variables.

Conclusions

- Ideas to keep in mind:
  - What is a sampling distribution? What does it imply about p-values and statistical significance?
  - When it is appropriate to use parametric versus non-parametric methods.
  - Most univariate and bivariate questions have a parametric and non-parametric approach.
- Homework assignment due next week.
- Next: Regression Analysis - looking at more complex relationships between more than 2 variables.

Conclusions

- Ideas to keep in mind:
  - What is a sampling distribution? What does it imply about p-values and statistical significance?
  - When it is appropriate to use parametric versus non-parametric methods.
  - Most univariate and bivariate questions have a parametric and non-parametric approach.
- Homework assignment due next week.
- Next: Regression Analysis - looking at more complex relationships between more than 2 variables.